# AUDITORY PROCESSING ABILITIES IN SCHOOL-AGED CHILDREN FROM THE REGION OF VOJVODINA

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***Abstract:*** *Auditory processing is the process of decoding an auditory stimulus along the hearing pathways in the central nervous system. Children with auditory processing difficulties face challenges in the transmission, processing, organisation, and use of auditory information. This affects their spoken language, reading abilities, writing acquisition, and academic achievements. The aim of this study was to assess the auditory processing abilities of school-aged children from the region of Vojvodina using the Battery test for Auditory Processing Disorders PSP1 (Heđever, 2017). This study also aimed to examine the influence of age, gender, and school success on auditory processing abilities in school-aged children. The study sample consisted of 162 children between the ages of 6.7 and 11.6 years. The PSP-1 test battery consists of 4 subtests: filtered words test, speech-in-noise test, dichotic word test, and dichotic sentence test. Results have shown that 8 (4.94%) respondents on the PSP1 test achieved below average results, indicating auditory processing difficulties. Among these respondents, two were female (1.24%) and six were male (3.70%). Four respondents (2.48%) belonged to the second age group (from 7.7 to 8.6 years) and two respondents (1.24%) belonged to the first (from 6.7 to 7.6 years) and the fourth age group (from 9.7 to 10.6 years) each. Statistically significant differences were observed in the auditory processing abilities of the respondents in relation to their age ($p < 0.001$) and gender ($p < 0.05$). Girls had significantly better results on the total score of the PSP1 test, as well as in two subtests: the filtered words test and the dichotic word test. In addition, there was a statistically significant correlation between auditory processing abilities and school success.*

***Keywords:*** *auditory processing, auditory processing disorder, school-aged children, PSP1 test*

## INTRODUCTION

Hearing is essential for normal oral communication, language, and cognitive development in humans. From the moment an auditory signal appears on the eardrum until its final recognition, a large number of mechanical and neurobiological processes take place (Babić, 2007). In addition to sound detection, understanding speech requires the ability to process, recognise, interpret, and respond to sound stimuli from the environment. These abilities depend on auditory processing (Musiek & Chermak, 2007).

Auditory processing includes a system of mechanisms and processes that involve perception, monitoring, identification, and discrimination of a sound signal. Auditory processing can be defined as decoding of auditory stimuli along the hearing pathway in the central nervous system (Abrams & Kraus, 2015). Abilities included in the auditory processing framework are localisation and lateralisation of the sound source, auditory discrimination, temporal (time) processing, and speech understanding in conditions difficult for listening (American Speech-Language-Hearing Association (ASHA), 2005).

Auditory processing disorder is a term used to describe people with normal hearing who have difficulties in receptive communication and/or language difficulties caused by problems in the perceptual processing of auditory information in the central nervous system (Sahli, 2009). One of the most cited definitions is the one given by the American Speech-Language-Hearing Association (ASHA, 2005). According to this definition, auditory processing disorder refers to difficulties in the processing of auditory information in the central nervous system that are not caused by a hearing impairment, or language and cognitive deficit. Although there are many definitions, most studies use four key criteria used to determine this disorder: hearing is normal, there is a neurological basis for the disorder, listening is impaired, and there are difficulties in the receiving, understanding, and using auditory information (Blaži et al., 2014).

Due to the lack of a unique and clear definition of auditory processing disorder, as well as variations in diagnostic criteria, studies also list different prevalences of this disorder. Chermak (2001) estimated that the prevalence of auditory processing disorder in the United States of America among school-aged children is between 2 and 5%. In research conducted among school-aged children in the United Kingdom, Hind et al., (2011) stated that the prevalence of auditory processing disorder was 5.1%. In a study conducted in Iran among participants aged 7 through 12 years, the prevalence of auditory processing disorder was 4.6% (Jarollahi et al., 2022). The Institute for Hearing Research in the United Kingdom estimated that 10% of children are diagnosed with auditory processing disorder (Institute of Hearing research (MRC), 2004).

Several studies have suggested that children's auditory processing skills improve as they develop, all the way up to adolescence (Amaral et al., 2013; Krizman et al., 2015; Lewandowska et al., 2021; Yathiraj & Vanaja, 2015). The improvement of auditory processing abilities in children is linked to the maturation of the brain (Tomlin & Rance, 2016). However, previous studies suggest that different auditory processes do not follow the same pattern of maturation, indicating different maturational courses for different auditory processes (Neijenhuis et al., 2002; Stollman et al., 2004).

Previous research findings on the impact of gender on auditory processing abilities are inconsistent. While most studies report no significant gender differences in auditory processing abilities (McDermott et al., 2016; Pedersen et al., 2017), some studies suggest that boys are more likely to experience auditory processing difficulties (Musiek & Chermak, 2007; Neijenhuis et al., 2002).

Children with auditory processing disorder have difficulties understanding speech and verbal instructions in a noisy environment, they have poor attention spans, as well as difficulties in spoken and written language (Mattsson et al., 2017). These difficulties often come to the forefront in the school environment due to the presence of background noise and increased reverberation, which is most often the case in classrooms (Heđever et al., 2013). Children with auditory processing difficulties struggle with attention, communication, and participation in group work. They commonly exhibit withdrawal in school, along with challenges in auditory memory, phoneme discrimination, reading, writing, and foreign language learning (Heđever & Bonetti, 2010).

Furthermore, auditory processing disorder is a common comorbidity that occurs along with other disorders, especially attention and hyperactivity disorder, specific learning difficulties (especially dyslexia), specific language disorders, and autism spectrum disorder (Mattson et al., 2017). The difficulties faced by children with auditory processing disorder are often not recognised and these children are characterised as poor pupils, which can also affect their social and emotional development (Choi et al., 2020 ; Kreisman et al., 2012; Lawton et al., 2017).

## AIM OF THE STUDY

The aim of this study was to assess the auditory processing abilities of school-aged children from the Vojvodina region of the Republic of Serbia. Furthermore, this study aimed to determine whether there are age and gender-related differences in auditory processing abilities in school-aged children as well as whether auditory processing abilities were related to school success.

Based on the aim of the study, we hypothesised that the PSP1 test battery is a good assessment tool for the detection of auditory processing difficulties in Serbian-speaking school-aged children. Another hypothesis was that auditory processing abilities assessed by the PSP1 test would align with the results of previous research in the following manner: auditory processing abilities will differ significantly in terms of age, but not gender, and that auditory processing abilities will be significantly related to school success of a child.

## RESEARCH METHODS

### Participants

The sample consisted of 162 school-aged children, of whom, 73 were boys (46.3%) and 87 were girls (53.7%). A convenience sampling strategy was used. All participants underwent a hearing screening test prior to school enrolment and had no history of hearing disability. The respondents were stratified into five groups based on age: the first age group consisted of respondents from 6 years and 7 months to 7 years and 6 months ($n$ = 33), the second age group consisted of respondents from 7 years and 7 months to 8 years and 6 months ($n$ = 32), the third age group consisted of respondents from 8 years and 7 months to 9 years and 6 months ($n$ = 31), the fourth age group consisted of respondents from 9 years and 7 months to 10 years and 6 months ($n$ = 34), and the fifth age group consisted of respondents from 10 years and 7 months to 11 years and 6 months ($n$ = 32). Results of the $\chi^2$ test revealed that the sample was uniform both according to gender ($p$ = 0.89) and age ($p$ = 0.99). The participants' school achievement ranged from a minimum grade of 3, indicating a good level, to a maximum grade of 5, representing an excellent level, in both overall school achievement and grades in the native language. The distribution of overall school achievement among the students was as follows: 1.2% achieved a good level (2 students), 12.3% reached a very good level (20 students), and 86.4% achieved an excellent level (140 students). When examining academic success specifically in the native language, the distribution was as follows: 3.1% attained a good level (5 students), 12.3% reached a very good level (20 students), and 84.6% achieved an excellent level (137 students).

### Research instrument

(1) Background information on all participants, including age, gender, and school success data, were obtained from school records. The data encompassed overall school achievement and the average grade in the participants' native language. Serbian schools employ a five-point grading system (unsatisfactory-1, satisfactory-2, good-3, very good-4, and excellent-5) to assess both overall and subject-specific achievements. These grades reflect the students' level of understanding, mastery of the subject matter, and overall academic performance. At the end of each academic term, students' overall achievement and achievement in each subject are determined by calculating the mean of their final grades. The study focused on evaluating the mean grades of second-, third-, and fourth-grade students. Success assessment of first-grade students was based on a four-point scale. This scale includes the following progress levels: progress is lower than expected, progress is consistent but slower, progress is at the expected level, and progress is above the expected level. To simplify data processing in this study, these progress levels were converted into grades ranging from 2 to 5.

Overall school achievement was considered to be an indicator of students' overall academic performance and it included their grades across multiple subjects. The inclusion of overall school achievement as a variable helped to analyse the potential influence of auditory processing difficulties on academic performance in a broader sense. The average grade in the native language refers to the average score or grade that a student receives in courses related to their first or primary language. This variable is useful in order to consider the potential impact of language barriers on overall academic achievement, which could also indicate auditory processing difficulties.

(2) The PSP1 test battery (Heđever, 2017) was used to assess auditory processing ability in children between the ages of 5.5 to 11.5 years. The PSP1 battery consists of 4 subtests: filtered words test, speech-in-noise test, dichotic word test, and dichotic sentence test.

The filtered words test (a low-pass filter with a cut-off frequency of 1 kHz and a damping slope of 32 dB/oct) is a monaural low-redundancy speech test. It is used to test word recognition ability in words whose intelligibility is reduced. The test consists of two lists of words, containing 17 monosyllabic words each, balanced by frequency and phonology for the left and right ear. Words for the left and right ear have an equal number of sounds in relation to the way and place of formation and are uniform according to the frequency spectrum.

The speech-in-noise test is, similar to the filtered words test, a monaural low-redundancy speech test used to examine the ability to understand speech in conditions difficult for listening. The test consists of two lists of 14 monosyllabic words for each ear that are phonologically well balanced and used frequently in everyday speech. Using words that are even based on phonology and frequency helps to ensure that the test is comparatively difficult when testing each ear. The words are given with the presence of background noise, which is presented with a completely incomprehensible continuous murmur of a great number of people with a uniform intensity 8 db lower than the intensity of the word-stimulus.

The dichotic word test is a binaural word test consisting of 30 monosyllabic word pairs (fifteen pairs per ear, 60 words in total) that are presented in both ears at the same time. The duration of the stimulus on both ears is equal and corresponds to 1 ms.

The dichotic sentence test is a binaural test consisting of 10 different sentence pairs per ear that are equalised by duration and the beginning of reproduction. The ability of the respondent to direct the attention to one ear and ignore the auditory stimulus on the other ear is tested.

Test results are obtained by adding up the correct answers, i.e., properly repeated words or sentences. The sum of all correct answers on the tests represent a total score on the PSP1 test. The maximum possible score on the filtered words test is 34, on the speech-in-noise test is 28, on the dichotic word test is 60, and on the dichotic sentence test is 20. The maximum possible score on the PSP1 test is 142.

Results achieved on the PSP1 test battery can be classified into three categories according to norms: average result, marginal result, and below average results indicating auditory processing difficulties. According to the PSP1 test norms, it is suspected that a child may have auditory processing disorder if they have obtained scores that fall below the average range on at least two subtests. All results that deviate by minus two standard deviations (or more) from the average are classified into the below average category (according to the author of the test, approximately 95% of the data should fall within one standard deviation from the mean; Heđever, 2020).

### Research process

The research was conducted in two primary schools in Novi Sad between March and June 2022. Written consent was obtained from the institutions and the parents prior to the start of the research study. Each child answered the PSP1 test individually in a quiet room using a computer and headphones. The research procedure was explained and a pretest practice was conducted to ensure that the participants understood the procedure. Left/right lateralisation ability was also assessed. The children’s responses were recorded on a special form and the test lasted approximately 30 minutes on average.

### Statistical analysis

Statistical analysis of the data was performed using SPS-S 20.0. The analysis included all 162 respondents who participated in the research. There was no missing data. Descriptive statistics measures were used, including measures of count (frequency and percentage), measures of central tendency (mean and median), and measures of variation (standard deviation and interquartile range). The Kolmogorov-Smirnov test was used to test for normality of distribution and inferential statistical tests such as Mann-Whitney U and Kruskal-Wallis tests were used for further analysis.

## RESULTS AND DISCUSSION

The results of Kolmogorov-Smirnov test used to assess the normality of distribution on the subtests showed that there was a deviation from the normal distribution in the overall results of the PSP1 test, as well as in the results of all tests, except for the dichotic sentence test (*p* > 0.05; Table 1).

**Table 1.** *Results of the Kolmogorov-Smirnov normality distribution test*

| Test | Kolmogorov-Smirnov | *p* |
|---|---|---|
| Filtered words test | 1.43 | 0.03 |
| Speech-in-noise test | 1.75 | 0.01 |
| Dichotic words test | 1.96 | 0.001 |
| Dichotic sentence test | 1.14 | 0.15 |
| PSP1 overall | 0.18 | < 0.001 |

Note: PSP1 overall – sum of the results of all tests

Due to a significant statistical deviation from the normal distribution, non-parametric tests were used in further analysis.

**Overview of the results obtained on the PSP1 test**

An overview of the results on the PSP1 test are shown in Table 2. The respondents achieved the best average result, i.e., 22.53 out of the possible 28 points (80.4%), on the speech-in-noise test. The respondents' average result on the dichotic sentence test was 15.60 out of the possible 20 points (78.0%). The respondents achieved lower average results on the filtered words test and the dichotic word test. The average result of the filtered words test was 25.30 out of the possible 34 points (74.4%), while the average result of the respondents on the dichotic word test was 44.55 out of the possible 60 points (74.2%).

**Table 2.** *Overview of the descriptive statistics of the PSP1 overall scores*

| Test | M | Mdn | SD | Min | Max | IQR | SE |
|---|---|---|---|---|---|---|---|
| Filtered words test | 25.30 | 25.58 | 4.42 | 6 | 34 | 6 | 0.34 |
| Speech-in-noise test | 22.53 | 23.00 | 2.79 | 11 | 28 | 4 | 0.22 |
| Dichotic words test | 44.55 | 46.00 | 8.85 | 16 | 57 | 11 | 0.70 |
| Dichotic sentence test | 15.60 | 16.50 | 3.52 | 4 | 20 | 4 | 0.28 |

Of the total sample, 8 respondents (4.94%) scored below average on at least 2 tests, indicating auditory processing difficulties and potential auditory processing disorder, according to the PSP1 test norms. Two of those 8 respondents were female (1.24%) and six were male (3.70%). Out of the total number of respondents with below average results, four respondents (2.48%) belonged to the second age group (7.7-8.6 years) and two respondents (1.24%) belonged to the first (6.7-7.6 years) and fourth age group (9.7-10.6 years) respectively.

The results obtained were in accordance with the expected results, as well as with the results of previous research. In research conducted by Heđever (2017), of the 600 children who participated, 4.4% of them achieved below average results on the PSP1 test, while in the research by Kantić and Alić (2020) 5.7% of the respondents achieved results indicating possible auditory processing disorder on the same test. Similarly, the results of research conducted by Ahmmed et al. (2014) indicated that 5.4% of school-aged children had poor auditory processing abilities. Other studies indicate different results. Nagao et al. (2016) established a lower prevalence for auditory processing disorders, which was 1.94% of a sample of 1,000 primary school pupils, while Moloudi et al. (2018) reported that 9.8% of the 396 students who participated in their study (ages 8-12 years) had auditory processing disorders.

The results on the PSP1 test battery according to categories (average, marginal, below average) are shown in Table 3. It can be noted that 96.3% of the respondents achieved an average result on the filtered words test, while 97.5% of them achieved an average result on the speech-in-noise test. On the dichotic word test, 71.6% of the respondents achieved average results, while 77.2% of respondents achieved an average result on the dichotic sentence test.

**Table 3.** *Overview of results indicating performance on the PSP1 subtests*

| Test | | *f* | % |
|---|---|---|---|
| Filtered words test | Average | 156 | 96.3 |
| | Marginal | 5 | 3.1 |
| | Below average | 1 | 0.6 |
| Speech-in-noise test | Average | 158 | 97.5 |
| | Marginal | 3 | 1.9 |
| | Below average | 1 | 0.6 |
| Dichotic words test | Average | 116 | 71.6 |
| | Marginal | 25 | 15.4 |
| | Below average | 21 | 13.0 |
| Dichotic sentence test | Average | 125 | 77.2 |
| | Marginal | 23 | 14.2 |
| | Below average | 14 | 8.6 |

Poorer results on the dichotic words test and the dichotic sentence test can be explained by the fact that auditory processing abilities are not completely developed by the ages of 7-12 years. Research shows that respondents aged 13 to 16 years have significantly better achievements on the dichotic tests than respondents aged 7 to 12 years (Lewandowska et al., 2021; Neijenhuis et al., 2002). The results obtained in the present study are in accordance with the results obtained in previous research. In a study by Skarzynski et al. (2015) conducted in a primary school in Poland, 7,642 pupils, aged 7 to 12 years, were screened for auditory processing difficulties. The results revealed that 11.3% of seven-year-old pupils and 9.7% of twelve-year-old pupils had poor results on the dichotic test. Satori et al. (2019) pointed out that dichotic tests best detect changes in the auditory processing abilities and that these tests are most effective when it comes to assessing the interhemispheric transfer of information and the maturity of the auditory system maturity. Santos et al. (2015) reached similar conclusions in their research. In the study conducted by Kantić and Alić (2020), respondents on the PSP1 test had the poorest results on the dichotic word test and 20.7% of them achieved results indicating a disorder. Similarly, Veličković (2017) reported that respondents had the poorest results on the dichotic word test.

### Overview of the results achieved on the PSP1 test in terms of gender of the respondents

Girls had better average achievements on all tests, as well as better overall results on the PSP1 test (Table 4). The overall results on the PSP1 test indicate that girls achieved an average result of 110.91, with a minimum of 61 points and a maximum of 135 points. The average results of the boys on the PSP1 test was 104.59, with a minimum of 52 points and a maximum of 136 points.

**Table 4.** *Overview of descriptive statistics of total scores on the PSP1 test in terms of gender*

| | Gender | *M* | *Mdn* | *SD* | *Min* | *Max* | *IQR* | *SE* |
|---|---|---|---|---|---|---|---|---|
| Filtered words test | Female | 26.26 | 27.00 | 3.68 | 15 | 31 | 5 | 0.39 |
| | Male | 24.17 | 25.00 | 4.93 | 6 | 34 | 5 | 0.57 |
| Speech-in-noise test | Female | 22.84 | 23.00 | 2.52 | 17 | 28 | 4 | 0.27 |
| | Male | 22.17 | 22.00 | 3.05 | 11 | 28 | 4 | 0.35 |
| Dichotic word test | Female | 45.79 | 46.38 | 8.66 | 16 | 57 | 10 | 0.93 |
| | Male | 43.11 | 45.00 | 8.91 | 20 | 57 | 11 | 1.03 |
| Dichotic sentence test | Female | 16.01 | 17.00 | 3.26 | 7 | 20 | 4 | 0.35 |
| | Male | 15.13 | 16.00 | 3.77 | 4 | 20 | 5 | 0.44 |
| PSP1 overall | Female | 110.91 | 113.00 | 15.46 | 61 | 135 | 21 | 1.66 |
| | Male | 104.59 | 107.00 | 18.11 | 52 | 136 | 24 | 2.09 |

Note: PSP1 overall indicates the sum of the results of all tests.
IQR, interquartile range; M, mean; Max, maximum; Mdn, median; Min, minimum; SD, standard deviation; SE, standard error

The results of the Mann-Whitney U test indicated that there was a significant difference in the overall results on the PSP1 test between boys and girls, suggesting that girls had significantly better overall results on the PSP1 test. In addition, girls had significantly better results than boys on the filtered words test and the dichotic word test. There was no significant difference in terms of gender either on the speech-in-noise test or the dichotic sentence test (Table 5).

**Table 5.** *Gender-related differences in the PSP1 test results based on results of the Mann-Whitney U test*

| Test | *U* | *p* |
|---|---|---|
| Filtered words test | 2392.00 | 0.003 |
| Speech-in-noise test | 2890.00 | 0.21 |
| Dichotic word test | 2618.00 | 0.03 |
| Dichotic sentence test | 2836.00 | 0.15 |
| PSP1 overall | 2603.50 | 0.03 |

Note: PSP1 overall indicates the sum of the results of all tests

The results obtained in the context of gender differences were not in accordance with the expectations or the results of many previous studies stating there were no gender-related differences in the auditory processing abilities of children (Daniel, 2013; Danneels et al., 2021; Mattsson et al., 2017; Satori et al., 2019; Tucman, 2016). The results obtained in the present study can be explained by the findings of Nanova et al. (2008) who showed that, between the ages of 7 and 10 years, developmental changes of the basic mechanism involved in auditory processing occur faster in girls than boys.

Krizman et al. (2019) pointed out that there are differences in auditory processing abilities in terms of gender and that these differences continuously and cumulatively increase with development. They pointed out that gender differences in the auditory processing abilities came from different subcortical activities in men and women during the processing of the auditory stimulus. The results obtained by Krizman et al. (2019) indicate that auditory processing difficulties were three times more common in boys. Blaži et al. (2014) had also established that girls had better results on auditory processing tests.

## Overview of the results achieved on the PSP1 test in terms of age

Descriptive statistics of the overall scores achieved on the PSP1 test battery in terms of the age groups of the respondents are shown in Table 6. The average achievement of the respondents on the PSP1 test battery showed an increase with age. Respondents of the first age group achieved the lowest average results on all tests, except for the filtered words tests, where the respondents of the second age group achieved the lowest average results (22.44; 66.0% accurate responses). Respondents of the first age group achieved the average result of 22.82 on this test (67.1% accurate responses). Respondents of the fifth age group achieved the highest average results on all tests. It can be noted that the respondents' achievement on the overall PSP-1 score also increased with age.

**Table 6.** *Overview of the descriptive statistics of the overall scores on the PSP1 test in terms of age*

| Test | *Age* | *M* | *Mdn* | *SD* | *Min* | *Max* | *IQR* | *SE* |
|---|---|---|---|---|---|---|---|---|
| Filtered words test | 6.7-7.6 years | 22.82 | 22.00 | 4.10 | 15 | 32 | 7 | 0.71 |
| | 7.7-8.6 years | 22.44 | 23.50 | 5.09 | 6 | 29 | 6 | 0.90 |
| | 8.7-9.6 years | 26.10 | 26.00 | 4.21 | 17 | 34 | 7 | 0.76 |
| | 9.7-10.6 years | 26.74 | 27.00 | 2.34 | 22 | 30 | 4 | 0.40 |
| | 10.7-11.6 years | 28.41 | 28.63 | 2.66 | 20 | 32 | 3 | 0.47 |
| Speech-in-noise test | 6.7-7.6 years | 20.55 | 21.00 | 2.11 | 17 | 25 | 3 | 0.37 |
| | 7.7-8.6 years | 21.38 | 21.00 | 3.54 | 11 | 28 | 5 | 0.63 |
| | 8.7-9.6 years | 22.87 | 23.00 | 1.78 | 20 | 28 | 2 | 0.32 |
| | 9.7-10.6 years | 22.79 | 23.00 | 2.06 | 17 | 26 | 9 | 0.35 |
| | 10.7-11.6 years | 25.13 | 26.00 | 1.74 | 21 | 27 | 2 | 0.31 |
| Dichotic word test | 6.7-7.6 years | 37.15 | 39.00 | 8.22 | 20 | 51 | 15 | 1.43 |
| | 7.7-8.6 years | 39.38 | 42.00 | 9.41 | 16 | 52 | 14 | 1.66 |
| | 8.7-9.6 years | 45.71 | 45.00 | 5.44 | 34 | 57 | 8 | 0.97 |
| | 9.7-10.6 years | 48.85 | 49.50 | 6.33 | 29 | 57 | 5 | 1.08 |
| | 10.7-11.6 years | 52.50 | 53.00 | 3.38 | 45 | 57 | 5 | 0.59 |
| Dichotic sentence test | 6.7-7.6 years | 12.27 | 13.00 | 3.36 | 4 | 18 | 4 | 0.58 |
| | 7.7-8.6 years | 13.63 | 14.00 | 3.48 | 7 | 20 | 6 | 0.61 |
| | 8.7-9.6 years | 16.42 | 16.00 | 2.16 | 10 | 20 | 2 | 0.39 |
| | 9.7-10.6 years | 17.12 | 17.50 | 2.28 | 10 | 20 | 1 | 0.39 |
| | 10.7-11.6 years | 18.63 | 19.00 | 1.48 | 14 | 20 | 2 | 0.26 |
| PSP1 overall | 6.7-7.6 years | 92.79 | 96.00 | 14.27 | 65 | 117 | 20 | 2.48 |
| | 7.7-8.6 years | 96.81 | 102.50 | 16.93 | 52 | 115 | 27 | 2.99 |
| | 8.7-9.6 years | 111.10 | 112.00 | 10.47 | 91 | 131 | 17 | 1.88 |
| | 9.7-10.6 years | 114.71 | 116.50 | 9.77 | 89 | 128 | 8 | 1.68 |
| | 10.7-11.6 years | 124.66 | 126.00 | 8.50 | 101 | 136 | 11 | 1.50 |

Note: PSP1 overall indicates the sum of the results of all tests
IQR, interquartile range; M, mean; Max, maximum; Mdn, median; Min, minimum; SD, standard deviation; SE, standard error

The results of the Kruskal-Wallis test indicate that there is a statistically significant difference in the scores of all tests, as well as the overall PSP1 test score, when we considered the age of the respondents ($p < 0.001$; Table 7). Older respondents achieved better results on the PSP1 test battery.

**Table 7.** *Results of the Kruskal-Wallis test in terms of age*

| Test | *H* | *df* | *p* |
|---|---|---|---|
| Filtered words test | 47.67 | 4 | < 0.001 |
| Speech-in-noise test | 55.85 | 4 | < 0.001 |
| Dichotic word test | 77.37 | 4 | < 0.001 |
| Dichotic sentence test | 78.76 | 4 | < 0.001 |
| PSP1 overall | 87.78 | 4 | < 0.001 |

Note: PSP1 overall indicates the sum of the results of all tests

The Kruskal-Wallis test was used to determine if there was a statistically significant difference in the results of the four subtests and the overall PSP1 test score in relation to the age of the child. A post-hoc analysis was conducted using the Scheffe test to determine which age groups had the most significant difference in the subtests and the overall PSP1 test score.

The significance values associated with the differences in the achieved scores across different age groups is shown in Table 8. As expected, the results of the Scheffe test showed that students in higher grades (older students) have significantly better results on the PSP1 test than those in lower grades.

**Table 8.** *Results of the Scheffe test for the PSP-1 test in terms of age*

| Age of a child | | Filtered words test | Speech-in-noise test | Dichotic word test | Dichotic sentence test | PSP over-all |
|---|---|---|---|---|---|---|
| in years | | ***p*** | ***p*** | ***p*** | ***p*** | ***p*** |
| 6.7-7.6 y | 7.7.-8.6 y | 0.99 | 0.73 | 0.79 | 0.38 | 0.77 |
| 6.7-7.6 y | 8.7-9.6 y | < 0.05 | 0.004 | < 0.001 | < 0.001 | < 0.001 |
| 6.7-7.6 y | 9.7-10.6 y | < 0.01 | 0.005 | < 0.001 | < 0.001 | < 0.001 |
| 6.7-7.6 y | 10.7-11.6 y | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| 7.7.-8.6 y | 8.7-9.6 y | 0.99 | 0.20 | 0.01 | 0.002 | 0.001 |
| 7.7.-8.6 y | 9.7-10.6 y | < 0.01 | < 0.01 | < 0.001 | < 0.001 | < 0.001 |
| 7.7.-8.6 y | 10.7-11.6 y | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| 8.7-9.6 y | 9.7-10.6 y | 0.97 | 0.99 | 0.76 | 0.89 | 0.85 |
| 8.7-9.6 y | 10.7-11.6 y | 0.22 | 0.007 | 0.005 | 0.03 | 0.001 |
| 9.7-10.6 y | 10.7-11.6 y | 0.53 | 0.004 | 0.15 | 0.26 | 0.03 |

In all four subtests, as well as on the overall score in the PSP1 test, the most significant differences were between first grade (6.7-7.6 years) and third grade (7.7.-8.6 years) students, first grade (6.7-7.6 years) and fourth grade (9.7-10.6 years) students, and first grade (6.7-7.6 years) and fifth grade (10.7-11.6 years) students. Additionally, there were significant differences between second grade (7.7-8.6 years) and fourth grade (9.7-10.6 years) students, as well as second grade (7.7-8.6 years) and fifth grade (10.7-11.6 years) students. No significant differences were registered between children in older grades (third to fifth grade) on the filtered words test.

The results indicating the existence of age-related differences in the auditory processing abilities of the respondents were in accordance with the expected results based on previous research. Heđever and Bonetti (2010) conducted a study with 143 primary school pupils and found a significant age-related difference in auditory processing abilities. Higher-grade students achieved better results, indicating an improvement in auditory processing with increasing grade level. Most other researchers reached similar results confirming a statistically significant difference in the auditory processing abilities in terms of age (Babkoff & Fostick, 2017; Danneels et al., 2021; Mattsson et al., 2017; Murphy & Schochat, 2009; Yathiraj & Vanaja, 2015). Moore et al. (2010) established that auditory processing abilities improved with the child's age based on a sample of 1,469 respondents aged 6 to 11 years, and that these abilities were significantly connected to communication and speech understanding in a noisy environment.

The results of the present study have shown that age differences are most noticeable on dichotic tests. In the study conducted by Satori et al. (2019), among early school-age participants, it was shown that dichotic testing reflects age-related changes in auditory processing abilities better than other tests. Moncrieff (2011) emphasised that the development of attention and language abilities also influences the improvement of dichotic listening skills with age.

## Correlation between the results achieved on the PSP1 test and school success

The correlation between the PSP1 test results and overall school achievement of the respondents is shown in Table 9. Spearman's correlation established a weakly significant correlation between the results of all subtests, as well as the PSP1 test and overall school achievement.

**Table 9.** *Correlation between the PSP1 test results and* overall school achievement

| Test | Filtered words test | Speech-in-noise test | Dichotic word test | Dichotic sentence test | PSP overall |
|---|---|---|---|---|---|
| School success | 0.18* | 0.17* | 0.26** | 0.23** | 0.26** |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Note: PSP1 overall indicates the sum of the results of all tests

A statistically significant correlation was also registered between the PSP1 test results and native language grades. Spearman's correlation established a statistically significant, but weak correlation between the results of the speech-in-noise test, the dichotic word test, the dichotic sentence test, and the overall PSP-1 test results with respect to the final grade in the native language. There was no relationship between the results achieved on the filtered words test and the grades in the native language (Table 10). The examination of the native language grade as a variable is important because children with auditory processing difficulties may face challenges in understanding spoken language, processing verbal instructions, and participating in classroom discussions. These difficulties can affect their ability to learn and utilise their native language, potentially resulting in academic difficulties in language-focused subjects such as reading, writing, and communication. (American Speech-Language-Hearing Association (ASHA), 2005; Bellis, 2003).

**Table 10.** *Correlation between the PSP-1 test results and native language grades*

| Test | Filtered words test | Speech-in-noise test | Dichotic word test | Dichotic sentence test | PSP-1overall |
|---|---|---|---|---|---|
| School success | 0.17* | 0.18* | 0.25** | 0.21** | 0.24** |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Note: PSP1 overall indicates the sum of the results of all tests

The results obtained by the present study were in accordance with the expectations and the results of previous research stating that auditory processing difficulties could be related to poorer language, reading, and writing abilities, as well as poorer academic achievement in general (Heđever & Bonetti, 2010; Heđever et al., 2013, Miller & Wastaff, 2011, Richard, 2007; Sharma et al., 2009). Several studies have pointed out the relationship between auditory processing disorder and particular reading difficulties (Fostick & Revah, 2018; Gokula et al., 2019; Hamalainen et al., 2015; Lovio et al., 2010; McDermott et al., 2016).

While the results obtained represent an important basis for recognising auditory processing difficulties in school-aged children, it is important to note some of the limitations of this study. Firstly, cognitive abilities were not assessed, thus, assuming that all children had average cognitive abilities since they were not classified differently when enrolling in school. However, cognitive factors such as attention, memory, and language abilities significantly influence auditory processing and deficits in these areas can impact a child's ability to accurately process and interpret sounds (Kraus & Chandrasekaran, 2010; Moore et al., 2010).

Another limitation is that the participants' hearing condition was not assessed beforehand since none of the subjects had reported hearing difficulties. However, it is important to acknowledge that hearing loss can significantly affect auditory processing. Peripheral hearing impairments or deficiencies in auditory information transmission can result in incomplete or inaccurate auditory information reaching the brain, and consequently, impact the individual's ability to process sounds accurately (Neijenhuis et al., 2002). However, since no assessment of hearing status was conducted prior to this study, it is possible that some of the participants had undetected (conductive or minimal sensorineural) hearing loss.

To build on current knowledge, recommendations for future research include investigating the effectiveness of different interventions and therapies for improving auditory processing abilities in children with detected auditory processing difficulties. Another recommendation is exploring the role of auditory processing abilities in overall school success, as well as the development of social communication skills, such as language pragmatics and theory of mind.

Even though the research on auditory processing abilities in Serbian-speaking children is limited (since it considered only the Vojvodina region), the results of the present study have shown that PSP1 is a valuable instrument for the identification of auditory processing difficulties in school-aged children. As far as we know, our study represents the first use of the PSP1 test battery in the assessment of auditory processing abilities in children in Serbia. While the PSP1 battery of tests was standardised and created in Croatia, it is also applicable for the Serbian-speaking population. Since there are currently no other standardised instruments for auditory processing assessment in Serbia, the application of the PSP1 battery of tests could significantly improve identification of auditory processing difficulties in this population.

Our findings revealed that 4.94% of school-aged children who took the PSP1 test scored below average, suggesting potential auditory processing difficulties. Older students achieved better results on the auditory processing test, indicating improved abilities with age. Gender differences were observed, with girls outperforming boys on the overall PSP1 test, as well as the challenging dichotic sentence and speech-in-noise tests. No significant gender differences were found in the dichotic word and filtered words tests. Auditory processing difficulties could impact academic achievement: there was a significant correlation between PSP1 test results and school success. Since auditory processing disorders can affect different aspects of children's lives, it is of great significance to detect these difficulties as soon as possible in order to provide children with the most adequate therapeutical approach based on their needs and abilities at a appropriate time. In order to diagnose a child with auditory processing disorder, it is necessary to include a multidisciplinary team, as well as the therapeutic approach in order to provide children with comprehensive development support.

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